

FOREST INSECT AND DISEASE RESEARCH

10-YEAR PLAN

August, 1989

LIBRARY COPY
ROCKY MTN. FOREST & RANGE
EXPERIMENT STATION

FOREST INSECT AND DISEASE RESEARCH 10-YEAR PLAN

EXECUTIVE SUMMARY

Forest insect and disease problems are expected to increase during the 1990's and into the 21st century for several reasons. (1) Stresses from global climate change and air pollution will increase the susceptibility of forests to the destructive effects of insect and disease pests; (2) these environmental changes can upset naturally evolved ecological balances, causing normally harmless insects and disease organisms to become pests; (3) increased commercial and recreational travel escalates the invasion and spread of exotic pests; and (4) expanding demands on the Nation's forests for goods and services lower the threshold of tolerance for sustaining pest damage. Public disfavor over use of traditional methods of control, such as chemical spraying and drastic or intensive silvicultural treatments, aggravates the dilemma by limiting the range of strategies available for combatting the rising tide of pest damage.

Intensified pest problems and loss of traditional pest control methods will create an urgent need for innovative countermeasures. Yet, the current forest insect and disease research program in the United States is insufficient to provide the needed technology. The current level of research effort cannot provide forest managers with adequate technology to protect the Nation's forests, meet management goals, and stay competitive in the international market.

In response to this situation, the Forest Service has prepared a 10-year plan for its insect and disease research program. The plan provides guidance to Station Directors and the Chief's office in program and budget planning and identifies priority areas of research under static, increasing, and decreasing budgets. The plan emphasizes the following research strategies for meeting the challenges of the 1990's and beyond.

- Increase the emphasis on fundamental research to provide a more complete understanding of pest organisms, host trees, the role of natural enemies, and interactions among these organisms as influenced by the environment. This understanding is essential for developing sound, ecologically-based integrated pest management strategies.
- Concentrate critical masses of skills and equipment to address important research questions.
- Improve research program flexibility to respond to new pest problems. Recent examples of new pest problems include dogwood anthracnose and pear thrips.
- Increase overall support for the program to meet the significant increase in cost of research, the demands for new technology, and the need for viable cooperative and extramural research with universities and other outside institutions and agencies.

FOREST INSECT AND DISEASE RESEARCH 10-YEAR PLAN

August, 1989

INTRODUCTION

Forest insects and diseases and wood-destroying organisms cause more than two billion dollars of damage each year to our Nation's forests and rangelands and to wood products and structures. Forest health is critical to our Nation's well-being, and the current levels of damage are unacceptable. Public agreement with this statement is evident through their frequent outcry over current pest-caused damage levels. Other issues add to and complicate the situation as we look to the future.

Global climate change and other environmental influences are projected to have significant adverse effects on the future health of our forests. These effects are expected to result in: stress-caused decline and mortality of selected tree species; increased susceptibility of trees to existing pests and the likely appearance of new ones; alteration of the rhizosphere that will influence both beneficial and damaging microorganisms.

Restrictions on, and public concerns over, the use of chemical pesticides to control forest pest outbreaks have increased in recent years. These concerns and limitations are expected to be even greater in the future.

Forest managers rely on research to provide effective and environmentally acceptable alternatives needed to cope with the pressing pest management needs of today and the even more demanding pest problems of the future. The current FIDR program is unable to keep pace with these demands.

These challenges must be met more aggressively and in a way that provides a stronger fundamental understanding of pest organisms, their natural regulating factors, the trees they affect, and related ecological and environmental interactions.

This plan was prepared to guide the Forest Service insect and disease research program at the national level to meet pest management needs into the next century.

VISION STATEMENT

The Forest Service has enjoyed the reputation of being an effective research organization with respect to insect and disease research. As we look to the future, we plan to further enhance this reputation. We envision that at the turn of the century:

- The FIDR program will be recognized nationally and internationally by Congress, forest management agencies, private companies, and environmental organizations as effective and responsive in providing solutions to forest insect and disease problems.
- The FIDR program will be developing new technology to significantly reduce damages caused by major forest pests, reduce associated environmental hazards, and lower costs of pest management.
- The FIDR program will be attracting and employing top scientists in an exciting, rewarding, productive, and highly-respected program.

MISSION AND GOALS

The mission of the USDA, Forest Service, Forest Insect and Disease Research (FIDR) program is to:

Provide knowledge and technology to prevent or reduce damage by forest pests and wood-destroying organisms in an effective, economic, and environmentally acceptable manner.

This mission can be accomplished most effectively through a balance of fundamental research aimed at developing new knowledge and innovative approaches and applied research that uses this basic knowledge to solve short-term or immediate problems.

In pursuit of this mission, we will:

- Provide managers with long-term strategies to prevent and reduce damage caused by major forest pests.
- Provide environmentally and economically acceptable methods to control pest outbreaks.
- Provide information and techniques to measure and predict pest-caused losses (including those exacerbated by air pollution and global climate change) and to evaluate the costs and benefits of management strategies so managers can make the most effective and environmentally sound pest management decisions.
- Provide safe and effective means of reducing damage from wood destroying insects and microorganisms.

PURPOSE OF THE 10-YEAR PLAN

This plan outlines a research program for the 1990's that will guide Forest Service Research into the 21st century. It will:

- Ensure that FIDR program management decisions over the next 10 years are consistent with national needs and priorities.
- Provide a framework for future planning to facilitate needed changes in FIDR program priorities and projects.
- Communicate the program's projected 10-year national direction to the field and to interested agencies and organizations.

PLANNING CONSIDERATIONS

The FIDR program has evolved over time to be more responsive to changing managerial, environmental, and economic demands. A few decades ago we simply looked for methods to kill or eliminate specific pests. We now seek to develop the technology and strategies to integrate pest management with other forest management activities. One goal is to prevent pest-caused damage by maintaining forest health. We also seek ways to reduce losses by thoroughly examining and evaluating outbreak conditions and projected consequences, then prescribing an appropriate integration of control strategies.

Our goal is to maintain a dynamic research program that is responsive to user needs. Forest Pest Management, the major user of our research output, needs to be intimately involved in research program development and our primary partner in technology transfer.

Global climate change and air pollution threaten to cause direct damage to forest trees and increase pest problems. To be responsive, the FIDR program must be fully integrated into the Forest Service's multidisciplinary research on global climate change.

We recognize the need to keep our research program ecologically oriented. A better understanding is needed of the effects, consequences, and interactions among various pests, management activities, and the environment.

FIDR seeks to solve problems of losses to forest resources from insects and diseases. Because these problems are typically complex and involve interactions among the various components of the forest ecosystem, the research is by necessity multi-functional. FIDR research must be integrated with the science of the host and resource, and the solution must integrate into the host and resource management systems. FIDR has a long history of cooperation with other disciplines in multi-functional research efforts. Most missions of FIDR Research Work Units are resource oriented and most list other non-FIDR RWU's as cooperators. We see a need to strengthen these cooperative ties through multidisciplinary Station programs that encourage RWU cooperation.

The current research program does not have the resources of personnel, equipment, and facilities to adequately address today's more complex management questions. Inflation was 224 percent during the period 1968 to 1988; the FIDR budget increased 221 percent in actual dollars between those years (from \$7.00 million to \$22.45 million). Thus, our purchasing power is virtually the same today as it was 20 years ago, but today's questions require more sophisticated answers and must come from increasingly more complex and expensive research. To achieve significant progress by the year 2000 toward the goals outlined in this document, the FIDR program needs to be doubled. We need additional scientists and require a significant increase in the average funding per scientist.

The future FIDR program must provide Forest Service and cooperating scientists with high-quality, modern facilities and equipment, and adequate professional and technical support. Research funding at a targeted appropriation level of \$150,000 per scientist during the past decade is now inadequate to meet current and future research needs. An appropriation level of \$250,000 per scientist is needed to support research in a manner that will more realistically accommodate the costs and expectations of the next decade. This level of funding includes funding for cooperative research with universities that is so essential to a productive, innovative program (see Appendix I).

RELATIONSHIP TO THE 1990 RPA PROGRAM

The 1990 RPA draft program presents national forest management options that vary according to how much emphasis will be given to commodity products, such as timber production, or to noncommodity resources, such as wildlife habitat. Although the selected option will greatly influence management of these forests, the decision should have little affect on the scope of the FIDR program. This

is because the FIDR program is directed toward developing the information and technology for protecting the forest resources of the Nation whether they are managed for commodities or for other resource considerations. Inadequacies in pest management technology will exist whether a forest is being managed for timber or recreation. The values to be protected can be equally as great in either case. Regardless of forest management objectives, more effective, environmentally acceptable, and economic pest management methods are needed to protect the basic forest resource.

Although the RPA option selected could result, for example, in less commodity production on national forest lands, the need for wood and wood products will not decrease. The FIDR program is responsible for developing pest management information and technology for forest managers regardless of ownership, be it Federal, State or private. Protection of forests for noncommodity considerations could lead to complicated pest management problems requiring innovative research solutions.

STATION PROGRAM PLANNING

A major purpose of this plan is to provide national direction for Station program development and budgeting. Tables 1 and 2 plus the following narratives describe where program emphasis should be placed. Stations should use these tables and text for guidance during all phases of program planning. In doing so, it is important to take the following into account.

1. The FIDR program needs to be expanded if Forest Service research is going to catch up with current needs in forest pest management, meet the needs of the first decade in the 21st century, and meet the other goals outlined in this document.
2. Current operating budgets per scientist are not adequate. (The average operating budget for FIDR scientists in FY 1988 was around \$37,000). Stations need to work toward achieving the goal of about \$100,000 per SY in terms of 1989 dollars (see Appendix I).
3. Stations having primary or lead responsibility for a pest whose geographic occurrence exceeds their Station boundary need to account for this broader responsibility in their program and budget planning.
4. Designation of a Station as having the lead responsibility in a research subject or pest does not preclude other Stations from doing research on this subject or pest. However, research should always be coordinated with the designated lead Station(s).
5. Meeting the goals outlined in this plan requires critical masses of skills, facilities, and equipment. Where these do not currently exist, especially in high priority research subjects and on high priority pests, Stations should strive to achieve them.
6. Static budget levels should not be interpreted as implying static programs. The current FIDR program is not keeping pace with the needs for innovative pest management techniques. Therefore, changes in the program are needed, even at current budget levels. At current budget levels the program cannot accomplish everything, and hard decisions must be made. Some research must be sacrificed in order to concentrate critical masses of skills and resources on the higher priority research.
7. Decreasing budgets, even more than static budgets, will require the reduction or elimination of some current research in order to keep other higher priority research viable. Stations are encouraged to make these hard choices rather than, "share the pain."
8. Increasing budgets should be used to strengthen priority research rather than, "share the wealth."
9. Stations should maintain the flexibility to redirect resources to emerging issues based on research needs following careful review. Current examples of new pest problems include pear thrips, dogwood anthracnose, Port Orford cedar root disease, and pitch canker.

THE FIDR PROGRAM

The FIDR program encompasses both basic and applied research: basic research to open new lines of investigation leading to innovative pest management approaches or to the removal of barriers to further research; and applied research that solves operational problems, such as evaluating new pesticides or developing silvicultural treatments. The program includes research

on pests of major national concern that cover large geographic segments of the country, and pests that are only of local concern. The program must be managed to provide support for long-term research needs with flexibility to meet emerging problems. The program is characterized as follows:

- A balance of basic and applied research will be maintained. We envision a ratio of approximately 60:40 (basic:applied) to be the overall goal. For specific pests or research subjects, however, the ratio will vary depending on priority research needs.
- Centers will be designated to concentrate research in key research subjects in an effort to maximize effective utilization of equipment, facilities, and skills. Examples include the impact assessment units at Research Triangle Park, NC and Fort Collins, CO; research on microbial control at Hamden, CT and Corvallis, OR; and seed and cone research at Athens, GA and Berkeley, CA.
- New research technology will be aggressively sought and applied.
- Major pests of national concern will receive highest priority (see list in Appendix II).
- Flexibility to respond to pests of local concern and emerging new pest problems will be maintained.

This program is described under three program areas that include 12 research subjects, and provides direction for program planning and budgeting. A short description of each research subject including the purpose, thrust, and Station responsibilities is given below. The program areas are:

1. ***Fundamental research.*** Provide fundamental knowledge and understanding to develop sound pest management systems and to overcome barriers to further research.
2. ***Operational research.*** Develop and test environmentally acceptable and cost effective prevention and suppression tactics and strategies.
3. ***Decision support research.*** Develop tools and procedures for survey, evaluation, impact assessment, and prediction for integrating pest management information into forest management decision making systems.

RESEARCH SUBJECTS

National direction and emphasis on the 12 research subjects are described in the following paragraphs. Tables 1 and 2 give recommended program emphasis under decreasing, static, and increasing budgets.

FUNDAMENTAL RESEARCH

■ PEST BIOLOGY

Purpose:

Build a foundation of fundamental knowledge about forest insect and disease pests upon which we can develop new and improved prevention and suppression strategies.

Research Thrust:

Research will be conducted on the biological characteristics of individuals and populations where problem analyses identify important key voids in our basic biological knowledge.

Station Responsibilities:

All Stations have responsibility as appropriate.

■ PEST TAXONOMY

Purpose:

Develop the taxonomic knowledge to support research and pest management programs; maintain the fungus culture collection.

Research Thrust:

Use classical and biotechnological approaches to differentiate taxa of similar host specific pathogenic root disease fungi from one another and from other similar non-pathogenic varieties. Insect taxonomy and taxonomy of fungi other than higher Basidiomycetes will be included only with substantial budget increases.

Station Responsibilities:

Primary responsibility for fungal taxonomy--FPL. Cooperating Stations for root disease organisms are: INT and NE (*Armillaria*), PNW (*Phellinus*), PSW (*Heterobasidion annosum*).

■ PEST GENETICS

Purpose:

Develop a basic understanding of how environmentally- and host-induced genetic changes in pests and pest populations influence pest behavior and population dynamics.

Research Thrust:

Determine the basic biochemical, physiological, and genetic differences between major pest populations that could explain observed differences in habits and population swings.

Station Responsibilities:

Lead Station for insect genetics--PSW; lead Stations for genetics of fusiform rust fungus--SE and SO.

■ **HOST/PEST/NATURAL ENEMIES/ENVIRONMENT INTERACTIONS**

Purpose:

Determine how hosts, pests, natural enemies, and the environment interact to affect the frequency and severity of pest-caused damage and impact.

Research Thrust:

Elucidate the interactive processes occurring between the pest, its host, other pests, natural enemies, and the environment leading to epidemics and outbreaks, and identify opportunities for the development of innovative control tactics. The research includes the role of environmental stresses on host physiology, attractiveness, and susceptibility. Evaluate the current and future influence of air pollution and climate change on insect and disease severity. Develop an understanding of the rhizosphere and its effect on tree growth, vigor, and pest susceptibility.

Station Responsibilities:

All Stations have responsibility for specific needs as applicable; lead Stations for fundamental research on host stress physiology--NC and RM; lead Stations for research on the rhizosphere--PNW and SE. (See Tables 3 and 4).

OPERATIONAL RESEARCH

■ **SILVICULTURAL TREATMENTS**

Purpose:

Develop silvicultural treatments that prevent and/or reduce pest-caused losses.

Research Thrust:

As fundamental research identifies opportunities for silviculturally-based controls, the appropriate stand treatments will be developed and tested.

Station Responsibilities:

Stations have responsibility for specific pests as applicable (see Table 4).

■ **CHEMICAL PESTICIDES**

Purpose:

Conduct research to support registration of promising pesticides for pests where other tactics are insufficient.

Research Thrust:

Test pesticides (primarily those that are commercially available) for efficacy in the laboratory and field, and determine the environmental hazard (including effects on non-target organisms) for those that show promise.

Station responsibilities:

Establish a national laboratory for evaluating pesticides and their environmental hazard. All Stations have responsibility, where appropriate, for pesticide and hazard research until a national laboratory is established.

■ **PESTICIDE APPLICATION TECHNOLOGY**

Purpose:

Improve pesticide delivery systems with emphasis on reducing drift, increasing spray accountability, and improving target deposition.

Research Thrust:

Develop aerial pesticide application systems for both chemical and microbial pesticides.

Station Responsibility:

Continue cooperative efforts on microbial pesticides--NE. Research will be in cooperation with other USDA Agencies.

■ **BIOLOGICAL CONTROL (*microbial pesticides*)**

Purpose:

Develop effective and environmentally safe microbial agents for non-chemical control of insect and disease pests.

Research Thrust:

Research will include the full range of insect pathology research including both the fundamental aspects of epizootiology and the more practical aspects of identifying and developing pathogens for use in control. Research will include formulation, production, field testing, application technology development, and examination of environmental hazard, including effects on non-target organisms. Biotechnology research will be conducted to improve virulence, host specificity, and other desirable characteristics of microbial pesticides. Research on fungal pests will include the use of endophytic organisms, hyperparasites, hypovirulence, microbial antagonism, and competition as biological controls of fungal diseases.

Station Responsibilities:

Lead Stations for microbial pesticides for major insect pests--NE and PNW; lead Station for biotechnology to enhance microbials--NE.

■ **BIOLOGICAL CONTROL (*behavioral chemicals*)**

Purpose:

Identify and evaluate behavioral chemicals, and develop strategies for their use in monitoring and suppressing insect pest populations.

Research Thrust:

Identify, synthesize, and formulate behavior chemicals for major forest pests, and test them for efficacy and environmental hazard. Develop strategies for deployment against major forest pests.

Station Responsibilities:

Lead Station--PNW. All Stations cooperate as appropriate.

■ **BIOLOGICAL CONTROL** (*parasites and predators*)

Purpose:

Develop control tactics using parasites and predators either through inundative release or establishment.

Research Thrust:

Emphasize introduction of parasites and predators of exotic forest pests. Develop tactics for the use of parasites and predators against native pests as fundamental research reveals opportunities.

Station Responsibility:

Lead Stations--NE (gypsy moth) and PSW (Hawaiian weed pests). Continue exploratory work with SPB--SO.

■ **HOST RESISTANCE**

Purpose:

Develop trees genetically-resistant to pests.

Research Thrust:

Find and understand resistant mechanisms, and develop stable resistance to selected major pests in tree species that are commonly propagated and planted in managed forests, seed orchards, windbreaks, and other special use areas. This research will follow both traditional lines of forest genetics and the more modern lines of bioengineering and somaclonal selection and propagation.

Station Responsibilities:

Lead Stations--PSW (white pine blister rust), SE and SO (fusiform rust), NC (somaclonal selection), PSW, NC, and SE (development of biotechnology methods).

DECISION SUPPORT RESEARCH

■ **DECISION SUPPORT SYSTEMS FOR IPM**

Purpose:

Provide resource managers with methods for integrating pest management information into all levels of forest management decisions.

Research Thrust:

Develop sampling and analysis systems for predicting the effects of pests and management practices on resource objectives. Determine costs and benefits of specific pest management strategies and develop methods for displaying these to managers, based on predictive models that can be integrated into decision support systems for project and area resource planning.

Station Responsibilities:

Lead Stations--RM (western U.S.) and SE (eastern U.S.). Other Stations cooperate by providing modelers with stand models and pest biology information and by field testing models as appropriate.

**LEAD
RESEARCH
RESPONSIBILITY**

Responsibility for conducting research lies with the Directors of the nine research Stations. Major responsibility for specific research subjects and pests are given in Tables 3 and 4. Station Directors having lead responsibility for a research subject or pest need to reflect this in their program and planning budget. Lead responsibility does not rule out other Stations from having active

research in these subjects or pests, but efforts should be thoroughly coordinated with the Station having lead responsibility. "Centers of concentration" will be designated for certain subject areas, as denoted in Tables 3 and 4. This concept implies that Stations should attempt to bring together critical masses of skills and equipment with sufficient operating budgets to effectively and responsively redeem these responsibilities. "Centers" denote a focused research program with a concentration of personnel and other resources at a single location.

**PRIORITY
PESTS**

Emphasis will be given to pests of highest national concern. Table 4 lists priority pests that are currently of high national concern and assigns Station(s) having major responsibilities. Designation of Stations having major responsibilities does not preclude other Stations from doing research on these pests. However, before other Stations include work on such a pest, they should thoroughly

coordinate their plans with the designated Station(s) to ensure that work is necessary and will not overlap. Also, Stations are encouraged where budgets permit to be responsive to research needs on new pest problems and on current pests not listed below. Close coordination is needed to maximize efficiency within the entire FIDR program. For more information concerning priority pests see Appendix II.

TABLE 1. PROGRAM DIRECTION BASED ON BUDGETS

RESEARCH SUBJECT	PURPOSE	DECREASING BUDGET	STATIC BUDGET (current level)	INCREASING BUDGET
PEST BIOLOGY	Build a foundation of fundamental knowledge upon which we can develop new improved prevention and suppression strategies.	Reduce budget, but give emphasis to pests currently causing major damage for which lack of knowledge limits development of acceptable strategies.	Maintain current budget level and give emphasis to major pests for which lack of knowledge limits development of acceptable strategies.	Increase program to include major pests not included in lower budget levels and pests of potential concern.
PEST TAXONOMY	Develop the taxonomic knowledge to support research and pest management programs.	Reduce research on taxonomy; maintain FPL fungal collection.	Maintain current program; continue to seek outside expertise on a case by case basis; maintain FPL fungal collection.	Expand Forest Service capability in fungal and insect taxonomy.
PEST GENETICS	Develop a basic understanding of how environmentally- and host-induced genetic changes influence pest populations.	Reduce current insect program; increase research on fusiform rust.	Maintain current level of emphasis for 5 years and evaluate continuing need and direction.	Maintain current level of emphasis for 5 years and evaluate continuing need and direction.
HOST/PEST/NATURAL ENEMIES/ENVIRONMENT INTERACTIONS	Determine how hosts, pests, natural enemies, and the environment interact to affect the frequency and severity of pest-caused damage and impacts.	Maintain program level, concentrating on the most serious pest problems.	Increase program, giving emphasis to major pests where knowledge limits development of improved pest management tactics and strategies; establish rhizosphere centers of emphasis.	Significantly increase research on major pests and on those with the potential to become major pests. Establish stress physiology centers of emphasis.
SILVICULTURAL CONTROL TREATMENTS	Develop silvicultural treatments that prevent and/or reduce pest-caused losses.	Reduce budget on development of silvicultural treatments to reduce pest-caused losses, emphasizing field testing of promising results from fundamental research.	Reduce budget on development of silvicultural treatments to reduce pest-caused losses, shifting savings to fundamental research in support of future silvicultural options.	Increase current level of effort on new silvicultural treatments, based on findings of fundamental research.
CHEMICAL PESTICIDES	Conduct research to support registration of promising pesticides for pests where other tactics are insufficient.	Reduce budget, restricting program to environmental hazard research on currently-used pesticides only.	Restrict current program to environmental hazard research and field testing promising pesticides only for major pests lacking alternative tactics.	Increase budget and expand the current program on the development of chemical pesticides. Emphasize work on major pests. When funding permits, establish chemical pesticide center.

TABLE 1. PROGRAM DIRECTION BASED ON BUDGETS (continued)

RESEARCH AREA	PURPOSE	DECREASING BUDGET	STATIC BUDGET (current level)	INCREASING BUDGET
PESTICIDE APPLICATION TECHNOLOGY	Improve pesticide delivery systems with emphasis on reducing drift, increasing spray accountability, and improving target deposition.	Eliminate all research.	Maintain current levels of cooperative effort.	Where resources permit, establish major effort in cooperation with other USDA Agencies.
BIOLOGICAL CONTROL (Microbial Pesticides)	Develop effective and environmentally safe microbial agents for nonchemical control of insects and disease pests.	Maintain current levels of funding, concentrating on gypsy moth and biotechnology program at Delaware.	Increase effort on western defoliators. Maintain gypsy moth and biotechnology efforts.	Increase level of effort in the eastern center for biocontrol and establish a western microbial pesticide center.
BIOLOGICAL CONTROL (Behavioral Chemicals)	Identify and evaluate behavioral chemicals, and develop strategies for their use in monitoring and suppressing insect pest populations.	Increase budget and program on the identification, synthesis, formulation, efficacy, testing for environmental hazard, and development of deployment strategies. Emphasize major western bark beetles and defoliators.	Increase budget and program on the identification, synthesis, formulation, efficacy, testing for environmental hazard, and development of deployment strategies. Emphasize major bark beetles, defoliators, and shoot and tip moths.	Increase budget and program on the identification, synthesis, formulation, efficacy, testing for environmental hazard, and development of deployment strategies. Establish national center.
BIOLOGICAL CONTROL (Parasites and Predators)	Develop control options using parasites and predators either through inundative release or establishment.	Reduce budget, except maintain current level against weed pests in Hawaii and against gypsy moth.	Reduce budget, except maintain current level against weed pests in Hawaii and against gypsy moth.	Increase level based on fundamental research on host/pest/natural enemies/environment and their interactions.
HOST RESISTANCE	Develop trees genetically resistant to pests.	Decrease budget and program. Reduce effort on fusiform rust and somaclonal development of resistant varieties.	Maintain current budget level nationally but shift some funds from fusiform rust to white pine blister rust.	Maintain current funding levels on fusiform rust, increase efforts on white pine blister rust and other appropriate pests. In cooperation with TMR, establish centers at Berkeley and Rhinelander for developing biotechnology tools.
DECISION SUPPORT SYSTEMS	Provide resource managers with methods for integrating pest management information into all levels of forest management systems.	Reduce budget, but emphasize SPB and fusiform rust in the East and WSBW and root diseases in the West.	Maintain current budget and program. Increase cooperative efforts with FPM (MAG). Increase cooperative efforts with the Forest Response Program and the FAI Program.	Increase budget and expand the program to include other major pests. Further strengthen cooperative effort with MAG.

TABLE 2. Emphasis given to research subject areas depending on static, increasing or decreasing budgets. ("-" means less emphasis than current program, "=" means no change, and "+" means greater emphasis.)

RESEARCH SUBJECTS	BUDGET		
	DECREASING	STATIC	INCREASING
Pest Biology	-	=	+
Pest Taxonomy	-	=	+
Pest Genetics	-	=	=
Host/Pest/Natural Enemies/Environment Interactions	=	+	++
Silvicultural Treatments	-	-	+
Chemical Pesticides	-	-	+
Pesticide Application Technology	-	=	++
Microbial Pesticides	=	+	++
Behavioral Chemicals	+	+	++
Parasites/Predators	-	-	+
Host Resistance	-	=	+
Decision Support Systems	-	=	+

TABLE 3. Station leadership responsibilities by research subject area.

RESEARCH SUBJECT	STATION								
	PNW	PSW	INT	RM	NC	NE	SE	SO	FPL
Pest Biology	X	X	X	X	X	X	X	X	X
Pest Taxonomy*	—	—	—	—	—	—	—	—	X
Pest Genetics	—	X	—	—	—	—	X	X	—
Host/Pest/Natural Enemies/Environment Interactions	X	X	X	X	X	X	X	X	X
Silvicultural Treatments	X	X	X	X	X	X	X	X	—
Chemical Pesticides*	-----National Laboratory-----								
Pesticide Application Technology*	—	—	—	—	—	X	—	—	—
Microbial Pesticides*	X	—	—	—	—	X	—	—	—
Behavioral Chemicals*	—	X	—	—	—	—	—	—	—
Parasite/Predator	—	X	—	—	—	X	—	—	—
Host Resistance	—	X	—	—	X	—	X	X	—
Decision Support Systems*	—	—	—	X	—	—	X	—	—

* Designated center. "Centers" denote a focused research program with a concentration of personnel and other resources at a single location.

TABLE 4. Designation of Stations having major responsibilities for research on pests of high national concern. (X indicates Stations with major responsibilities.)

PEST	STATION								
	PNW	PSW	INT	RM	NC	NE	SE	SO	FPL
Gypsy Moth	—	—	—	—	—	X	—	—	—
Southern Pine Beetle	—	—	—	—	—	—	—	X	—
Mountain Pine Beetle	—	—	X	—	—	—	—	—	—
Western Spruce Budworm	X	—	—	—	—	—	—	—	—
Tussock Moth	X	—	—	—	—	—	—	—	—
Cone and Seed Insects	—	X	—	—	—	—	X	—	—
Wood Products Pests	—	—	—	—	—	—	—	X	X
Air Pollution	—	X	—	—	—	X	—	—	—
Dwarf Mistletoes	—	—	—	X	—	—	—	—	—
Root Diseases	X	X	X	—	—	X	—	—	X
Fusiform Rust	—	—	—	—	—	—	X	—	—
Forest Declines	—	—	—	—	—	X	—	X	—
Rhizosphere	X	—	—	—	—	—	X	—	—
Shelterbelt Pests	—	—	—	X	—	—	—	—	—

APPENDIX I

ESTIMATE OF AVERAGE APPROPRIATION LEVEL FUNDING REQUIRED PER SCIENTIST PER YEAR IN FIDR

FIDR needs to support its scientists with technician support, equipment and operating budgets commensurate with the assigned tasks. High quality, up-to-date equipment, facilities, scientific skills, and professional and technical support are required to make meaningful research progress. The FIDR staff believes an appropriation level funding of \$250,000 per scientist per year is required. This is supported by the following:

\$ 50,000--average salary costs for a scientist
50,000--average salary costs for two permanent technicians
5,000--average per-scientist cost for clerical support
5,000--fixed costs (lights, heat, phones, etc.)
15,000--Washington Office overhead
28,000--station overhead
97,000--per scientist operating budget ¹
\$250,000--total

¹ This recommended operating budget per scientist is based on the following factors:

- (a) The operating budget must cover supplies, equipment, travel and computer costs directly associated with the research and training. It also must cover all extramural research, including cooperative agreements and contracts.
- (b) The cost of extramural research has increased significantly in the past decade due to inflation, real increases in research costs, and a significant increase in overhead charges. It is typical for a single contract today to be as high as \$50,000, or approximately one-half of the proposed per scientist operating budget.
- (c) The cost of doing research has increased significantly beyond inflation. Instruments required to meet today's analytical standards cost significantly more than the equipment needed to meet yesterday's standards. For example, equipping a biotechnology laboratory costs several hundred thousand dollars.

APPENDIX II

CURRENT PRIORITY PESTS OF NATIONAL CONCERN

Following is a listing of the major pests and a description of the research planned on each pest.

Gypsy Moth. The primary center for gypsy moth research will remain in the NE Station. Research will be on the biology, ecology, population dynamics, and host relations and on developing and testing controls for gypsy moth. Techniques to describe and predict impacts, develop guidelines, and determine the effects of biological controls will be developed. Exploration of biotechnological approaches to enhance microbial insecticides will continue. Research on physiological tree stress as it may relate to gypsy moth infestations will be conducted in the NC in their host stress physiology unit. Chemical pesticide support will be provided by the national chemical pesticide unit. Basic pheromone research and insect physiology research will be conducted in cooperation with PNW and PSW Stations, respectively.

Southern Pine Beetle. Research on all aspects of southern pine beetle biology, ecology, and management will be centered in SO Station. Adaptation of findings to forest types and management objectives in other areas of the southern pine beetle range will be through collaborative studies with universities or other Forest Service units. Impact prediction methods will be developed by the SE Station impact research unit. Pheromone chemistry support will be provided by PNW Station pheromone research unit.

Mountain pine beetle. Research on the ecology and silvicultural control of mountain pine beetle will be conducted mainly by the INT Station. Host/beetle relationships during non-outbreak periods will be studied to develop more refined hazard rating systems. Research will be continued on understanding the response of beetles to tree and stand factors, including tree spacing and the stand microenvironment.

Western Spruce Budworm. The center for western spruce budworm research will be the PNW Station. Primary emphasis of this research will be on studies of growth, development, and management of forest stands that serve as budworm hosts and will include the actions and interactions of the western spruce budworm and associated organisms in these stands. The PNW will serve as the primary research station for developing biological data, as the contact point for western budworm technology, and as coordinator of field testing of pheromones, microbial insecticides, and other research outputs. RM will conduct research on the biology of WSBW as related to development of decision support systems and assessment of impacts. Research at the RM Station will also include studies on the physiology of the WSBW in relation to available host nutrients. Research at INT will emphasize silvicultural control. Interdisciplinary support will be provided by appropriate Timber Management Research units and by FIDR impact, pheromone, and pesticide research specialists.

Douglas-fir Tussock Moth. Research on the silvicultural control and the development of effective microbial insecticides and deployment of semio-chemicals to suppress emerging populations will be done by the PNW Station.

Cone and Seed Insects. Primary responsibility for seed and cone insect research will be with SE Station in the East and with the PSW Station in the West. These Stations will have responsibility for identifying causes of seed and cone losses, developing biological understanding, and prescribing techniques for reducing losses of cones and seeds in seed orchards and seed production areas. These units will work with specialists in chemical and microbial pesticide centers, impact centers, pheromone units, and others as appropriate to provide guidelines and methods for reducing cone and seed losses.

Wood Products Insects and Decay. Research on insects and decay organisms affecting wood in use will be conducted by SO Station (insects), and the FPL (decay). Research at the Gulfport laboratory will emphasize the study of biology, habits, and control of termites and wood-destroying beetles. FPL will conduct research on the fundamental breakdown of wood by fungi and on developing biological and chemical methods to control wood destroying fungi.

Air Pollution. Air pollution research under FIDR funding will be located at the PSW and NE Stations. These efforts will develop an understanding of how air pollutants and acid rain directly affect forest growth, composition, health, and mortality, and how pollution damage can act indirectly as a predisposing agent for forest pests. The FIDR program, with primary responsibility for providing research on the disease effects of air pollutants and atmospheric deposition on forest trees and plants, will continue to cooperate in the current forest response program and integrate this research effort into the Forest/Atmosphere Interaction PRP. The SE Station will develop methods for determining the impacts of air pollution on forest resources.

Dwarf Mistletoes. Research will be aimed at developing dwarf mistletoe impact models that can be integrated into various growth and yield models to predict the impacts of this pest with and without a variety of control measures. The RM Station will have the lead in this impact work, but other stations will be involved in supplying the biological information needed to build the model and in assisting with model validation.

Root Diseases. Research on the biology and control of western root diseases will be conducted on three major root pathogens: *Heterobasidion annosum* at the PSW Station, *Phellinus weirii* at the PNW Station, and *Armillaria* spp. in the INT Station. Research on root diseases of eastern species will be conducted by the NE Station. These efforts will focus on understanding the infection processes, spread, host range, relative resistance of host trees, and other biological characteristics that would be useful in developing silvicultural controls for these pests. In addition, research will be conducted on the taxonomy of root disease fungi at the FPL, and on the impacts of root diseases at the RM Station.

Fusiform rust. Fusiform rust research will focus on understanding host resistance mechanisms and developing resistant varieties and will be mainly centered at the SE Station. However, an appropriate level of FIDR input and support will be provided to the SO Station's southern pine genetics program. Rust impact research will be conducted by the impact unit in the SE Station.

Forest Declines. Research on the causes and processes involved in forest declines of hardwoods will be conducted by the NE and SO Stations. This work will concentrate on identifying the causes of decline and include investigations into possible biotic as well as abiotic causes and on interactions of multiple pests.

Rhizosphere. Research on the biological composition and role of the rhizosphere as it effects the host tree, its form and growth, and its susceptibility to forest insects and diseases will be investigated at the PNW and SE. Environmental effects of air pollution and changing climate on the rhizosphere and its host tree will be studied at the SE.

Shelterbelt pests. Research on pests of shelterbelts of the Great Plains will be conducted at the RM Station and will be directed at developing practical management systems. Emphasis will be placed on studies to develop an understanding of host/environment/pest interactions. The research will concentrate on identifying stress- and pest-tolerant host species, determining the physiological mechanisms of host resistance, and understanding the interactions of these resistance mechanisms with environmental factors.